Financial Reforms, Patent Protection and Knowledge Accumulation in India

James Ang

Monash University

2009

FINANCIAL REFORMS, PATENT PROTECTION AND KNOWLEDGE ACCUMULATION IN INDIA

James B. Ang *

Department of Economics

Monash University

Abstract

The main objective of this paper is to explore the impact of financial sector reforms, financial deepening and intellectual property protection on the accumulation of knowledge for one of the world's largest developing countries. The findings indicate that increased intellectual property rights protection is associated with higher knowledge accumulation. While financial deepening facilitates the accumulation of ideas, the implementation of a series of financial liberalization policies is found to have a non-linear effect. The results show that financial liberalization will exert a beneficial impact on technological deepening only if the financial system is sufficiently liberalized.

Keywords: financial liberalization; ideas production; endogenous growth; India.

JEL classification: E44; E58; O30; O53

* Department of Economics, Monash University, 900 Dandenong Road, Caulfield East, Vic 3145 Australia. E-mail: James.Ang@buseco.monash.edu.au. Tel: +603-99034516.

1. Introduction

Recent literature on endogenous growth theory suggests that there is a strong positive correlation between R&D activity and economic growth (Grossman and Helpman, 1991; Jones, 1995a; Aghion and Howitt, 1998; Segerstrom, 1998; Jones, 2002; Aghion *et al.*, 2005; Laincz and Peretto, 2006).[1] However, although the relevant literature has emphasized the role of R&D in stimulating productivity growth, studies so far have not explored how financial liberalization and financial deepening affect innovative activity. Little attention has also been paid to understanding how patent protection influences knowledge creation. Better access to finance facilitates the adoption of modern technology to boost development of the knowledge and technology-intensive industries through reducing moral hazard problems and providing efficient credit facilities. On the other hand, the fundamental objective of having a better patent protection framework is to promote the creation and diffusion of technology by providing the inventors with some monopolistic power.

This study is related to two strands of literature. One has explored the effects of intellectual property protection on economic growth (e.g., Gould and Gruben, 1996; Park and Ginarte, 1997; Falvey *et al.*, 2006). The other strand has tried to assess the impact of financial reforms or financial deepening on economic growth (e.g., Demetriades and Hussein, 1996; Arestis and Demetriades, 1997; Edison *et al.*, 2002; Beck and Levine, 2004; Rioja and Valev, 2004; Bekaert *et al.*, 2005; Rousseau and Vuthipadadorn, 2005; Mavrotas and Son, 2006; Ang, 2008). However, none of these studies has attempted to examine the roles of finance or intellectual property rights protection in determining growth rates via the channel of knowledge production.[2]

Moreover, although the literature has identified both finance and patent protection as important determinants for innovative activity, these two factors have often been analyzed in isolation and so far no attempt has been made to assess them in an integrated framework. In line with this, Liodakis (2008) argues that both intellectual property protection and finance have emerged to be the two pillars of the development of technological innovations in recent years,

[1] There is an active debate concerning the functional relationship between R&D and growth. Jones (1995b) dismisses the first-generation growth models of Romer (1990) and Aghion and Howitt (1992) by showing that the TFP growth rates in the G5 economies have not increased during the post WWII period, despite a significant increase in the number of R&D workers. His ideas production model assumes diminishing returns to knowledge so that a positive growth in R&D is required for sustaining a positive TFP growth. However, the Schumpeterian growth models of Aghion and Howitt (1998), Peretto (1998) and Howitt (1999) retain the assumption of constant returns to knowledge from the first-generation models, but argue that the effects of the increasing level of resources devoted to R&D are sterilized by the concomitant increase in product variety in the economy. See Ha and Howitt (2007) for more details.

[2] Some exceptions include Kanwar and Evenson (2003) and Kanwar (2007), who study the effects of intellectual property protection on the share of R&D expenditure in GNP, and Lerner (2009), who examines the impact of patent system on patent applications. Our study, however, focuses on the impact of patent protection on the stock of ideas. Empirical evidence on the effect of finance on R&D investment is generally limited to firm-level analysis (see, e.g., Hall, 1992; Himmelberg and Petersen, 1994). An exception is the recent study by Ang (2009c), who shows that financial reforms in Korea tend to increase the generation of new ideas.

highlighting the importance of considering them under a single framework. This consideration is important given that banks may not want to finance risky innovative activities unless the protection framework of intellectual property rights is sufficiently strong. Thus, the provision of finance for innovative activities may be constrained by the appropriability conditions. On the other hand, the law makers may not want to strengthen the protection framework unless a proper institutional framework is in place in the financial system. Similarly, Kanwar and Evenson (2009) show that a country is able to provide a higher level of patent protection if the government has better access to financial resources. Thus, finance and patent protection may be strongly associated, and the consideration of these factors in an integrated framework is necessary to provide a more complete analysis.

We aim to enrich the existing literature by providing further evidence on how finance and protection of intellectual property affect ideas production, drawing on the experience of one of the largest developing economies in the world. We focus our analysis on the Indian experience due to several reasons. Research on the relationship between R&D and growth has focused exclusively on the U.S. and OECD countries due to the lack of R&D data for developing countries. Despite the fact that they suffer more from a knowledge gap, so far there has been little evidence documented for developing countries. India is an ideal candidate in this context given that it is one of the world's fastest growing developing countries. Its large population, representing about 17 percent of the world total, together with a substantial pool of workers engaged in R&D, provides an adequate basis for the use of an R&D-induced endogenous growth framework to test the underlying hypotheses.

We focus on documenting case studies evidence since this approach is more useful in disentangling the complexity of the financial and legal environments and economic histories of an individual country, and is therefore helpful in identifying reasons for growth variations within the country. By analyzing case studies, the econometric findings of this project can be related to the prevailing institutional structure, and therefore inform academic as well as policy debate. Moreover, the availability of long time series data on R&D going back as far as 1950 provides an added incentive for this research given that R&D data are particularly scant. In this connection, it is worth noting that a majority of the OECD countries have data starting only from 1970 (see, e.g., Coe and Helpman, 1995). The availability of a set of sufficiently long time series data allows for a meaningful time series investigation. This is important given that economic growth is a long-run phenomenon, which necessitates analyzing the evolution of the variables of interest over time in order to relate the findings to policy designs (Solow, 2001).

More importantly, India's recent financial sector and patent system reforms provide an ideal testing ground for further analyzing the relationship between finance, patent protection and knowledge production. There was little intervention in the financial system of India during the 1950s and 1960s. However, the government gradually imposed more controls by raising statutory liquidity and cash reserve requirements over the 1970s and 1980s. Furthermore, several interest rate controls were implemented in the late 1980s. A series of comprehensive financial sector reform policies were undertaken in 1991 as part of broader economic reform. These were aimed at changing the entire orientation of India's financial development strategy from one of repression towards encouraging a more open, market-type system. Since then, interest rates were gradually liberalized and statutory liquidity requirements significantly reduced so that markets could play a greater role in price determination and resource allocation.

The industrial licensing requirements that restricted entry and expansion of both domestic and foreign firms were relaxed in the same year. The equity market was formally liberalized in 1992, although the first country fund was set up earlier in 1986, allowing foreign investors to access the domestic equity market directly. Capital account restrictions were also reduced. The regulatory framework was strengthened significantly in 1992. In addition, entry restrictions were deregulated in 1993, resulting in the establishment of more private and foreign banks. Consequently, regulations on portfolio and direct investment were eased. The exchange rate was also unified in 1993-94 and most restrictions on current account transactions were eliminated in 1994 (see also Ang, 2009a, b).

India has a long history of patent system policy, which can be traced back to Act VI of 1856 on Protection of Inventions. However, under this Act, the Indian patent system has failed to stimulate the development of domestic inventions. A majority of the patents were filed by foreigners, who enjoyed significant monopolistic power in the market. In view of these limitations, the Patents Act of 1970 was enacted with the objective of promoting more domestic inventions and reducing the monopoly power of foreign firms. This led to some restrictions on patentable items and duration of protection. Although this policy change was strongly supported by domestic firms, there was no significant variation in the number of patents filed by domestic residents over the next two decades. In 1989, under significant external trade threats from developed countries, India reversed its position and agreed to include intellectual property rights in the negotiations of the General Agreement on Tariffs and Trade (GATT).

Furthermore, following the economic liberalization launched in the early 1990s, India has attached greater importance to developing an intellectual property rights protection system. This was mainly motivated by the objective of attracting more foreign research which would potentially benefit the domestic research sector. This pro-patent reform position has subsequently led to the establishment of the 1999 Patents (Amendment) Act. More recently, India has revised its patent policy to conform to the Trade Related Aspects of Intellectual Property Rights (TRIPS) requirements. The Patent Act was further revised in 2005 to include more patentable items such as pharmaceutical and agricultural chemical products. The significant increase in patent applications in recent years reflects the filing of inventions which were not patentable under the 1970 Act.

It is probable that one of the key indicators of the impact of these reforms has appeared in the form of a significant variation in innovative activities. As such, these policy changes provide an appropriate historical setting to analyze the subject at hand. The rest of the paper is organized as follows. Section 2 sets out the R&D-induced endogenous growth models. The effects of finance and patent protection on innovative activity are tested based on a semi-endogenous growth model with appropriate modifications. Specifically, we incorporate two institutional factors - liberalization or deepening of the financial system and the patent protection framework - into our analysis of the determinants of ideas accumulation. Section 3 discusses construction of variables and data sources. The estimation techniques are described in Section 4. Section 5 performs the empirical analysis and presents the results. Section 6 checks the robustness of the results. The last section concludes.

2. A Simple Knowledge Creation Function and Its Extensions

2.1 The ideas production function

The R&D-based endogenous growth models of Jones (1995a), Kortum (1997) and Segerstrom (1998) can be summarized as follows:

$$Y_t = K_t^{\alpha}(AL)_t^{1-\alpha}, \quad 0 < \alpha < 1, \tag{1}$$

and

$$g_A = \frac{\dot{A}_t}{A_t} = \lambda X_t^{\delta} A_t^{\phi-1}, \quad 0 < \delta \leq 1, \quad \phi < 1, \tag{2}$$

where Y_t is total output, K_t is physical capital, A_t is total factor productivity (TFP) or the stock of knowledge in the economy, L_t is labor force, X_t is R&D input such as R&D personnel or R&D expenditure, λ is a research productivity parameter, δ is the research duplication parameter (0 if all innovations are duplications and 1 if there are no duplicating innovations), and ϕ measures the extent of externalities in the process of R&D. An increase in the level of R&D input should increase the growth rate of ideas production, but the relationship is not monotonic since the rate of discovery will decrease with the level of knowledge given that it is increasingly difficult to find the next new ideas so that $\phi < 1$ (Jones, 1995b). Eq. (2) sets out the analytical framework underlying our empirical modeling strategy. We will augment this analytical expression to consider the potential effects of finance and patent protection on inventive activity, as discussed below.

2.2. Finance and innovative activity

In their seminal work, McKinnon (1973) and Shaw (1973) noted that financial repression policies were largely accountable for the poor economic performance of developing countries in the 1960s, where low saving and credit rationing were widely observed. Investment suffered both in terms of quantity and quality as funds were allocated at the discretion of policy makers. They proposed that distortions in financial systems, such as loans issued at artificially low interest rates, directed credit programs, and high reserve requirements would reduce saving, retard capital accumulation, and prevent efficient resource allocation. The elimination of these distortions would therefore foster growth.

Recent developments in the theories of endogenous growth that consider financial factors are in line with the McKinnon-Shaw thesis. Financial liberalization facilitates inventive activity for a number of reasons. In the work of de la Fuente and Marín (1996), the relationship between finance and growth is analyzed in a model of product innovation in which efficiency of the financial system arises endogenously. Risk aversion and private information in R&D activity lead to a moral hazard problem, and this makes innovative activity unattractive for risk-averse entrepreneurs. This problem, however, can be mitigated through improved monitoring by the financial systems, which allow intermediaries to offer better insurance terms. Hence, more efficient financial systems should yield a higher level of innovative activity (see Ang and Madsen, 2008).

Using a product variety model, Blackburn and Hung (1998) argue that firms have incentives to hide successful R&D activity to avoid repaying their loans. Such a problem of moral hazard gives rise to the enforcement of an incentive-compatible loan contract through a costly monitoring system. In their model, greater financial liberalization allows financial intermediaries to diversify among a large number of projects that reduces delegation costs significantly. Lower costs of monitoring therefore spur innovative activity and technological deepening. Furthermore, in the endogenous growth model developed by Aghion *et al.* (2005), it is argued that firms can conceal the results of successful innovations and thereby avoid repaying their creditors. A low degree of creditor protection makes fraud an inexpensive option, and this limits firms' access to external finance, which discourages the production of new ideas. Financial reforms and deepening may increase the hiding costs through providing better laws and institutions. This makes credit more readily available to entrepreneurs and allows them to undertake innovative activity. More recently, in the Schumpeterian growth models with credit constraints developed by Aghion and Howitt (2009, Ch. 6), financial development results in lower screening and monitoring costs, thus mitigating agency problems and increasing the frequency of innovations.

While the positive impact of financial deepening is clear, the view regarding how financial liberalization influences knowledge generation is not universal. Some counter arguments suggest that financial liberalization may not necessarily lead to higher innovative activity. For instance, Stiglitz (1994) argues that government intervention by way of repressing financial systems can reduce market failures and improve the overall performance of an economy. For example, keeping interest rates at low levels can raise the average quality of borrowers. Imposing credit constraints can also encourage the issue of more equity to finance business expansion. This lowers the cost of capital. Furthermore, directed credit programs can channel resources to high technological spill-over sectors. Similarly, Mankiw (1986) proposes that government intervention, such as providing a credit subsidy and acting as a lender for certain borrowers, can substantially improve the efficiency of credit allocation. Hence, the impact of financial liberalization on ideas accumulation is theoretically ambiguous.

2.3 Patent rights and innovative activity

Intellectual property rights protection may play an important role in stimulating growth through influencing the incentives to innovate. Gould and Gruben (1996) argue that intellectual property rights will increase the rate of innovative activity through the provision of an environment conducive to the accumulation of knowledge. Jaffe and Lerner (2004) propose that, in principle, patent protection may provide adequate incentives for the creators of new technology to innovate, through protecting their future profits, thereby stimulating technological inventions. Maskus (2000) and O'Donoghue and Zweimüller (2005) argue that greater patent protection facilitates the accumulation of knowledge, given that the information in patent claims is available to future innovators or that patent policy is also useful in counteracting entrepreneurs' inclination to pursue suboptimal innovations.

However, the theoretical effect of patent protection on economic growth is not always unambiguous, and there are counter arguments as well. For instance, using a dynamic general equilibrium model, Segerstrom *et al.* (1990) show that increasing the duration of patents can either stimulate or retard innovative activity. This is because while longer patents tend to increase the return on R&D, they also require more resources to be channeled to produce existing products. Using a dynamic general equilibrium model of the international product life cycle, Lai (1998) shows that strengthening the level of patent protection will lead to an increase in the rate of product innovation if foreign direct investment is the channel of international technology diffusion. However, the opposite effect is obtained if production is channeled through imitation.

Studies have also shown that patent protection may retard technological innovation. For instance, Gilbert and Newbery (1982) show that strong protection of intellectual property rights may provide incentives for a monopoly to patent new technologies before potential competitors in order to prevent entry of other firms and preserve its market share. This will reduce the rate of technical innovation. Using a dynamic general equilibrium model, Helpman (1993) shows that stronger protection increases the rate of innovation only in the short run due to higher profitability. In the long run, however, it lowers the rate of innovation as firms tend to produce old-technology products that take away resources from innovative activity. More recently, Boldrin and Levine (2008) argue that patent protection can be used as a tool to hurt competitors, as the grant of a monopoly over a new invention may block the development of another equally useful innovation, thereby retarding technological development. Since innovators' property rights can still be protected even without patents and copyrights, they argue that intellectual monopoly is an unnecessary evil. In line with this, Jaffe and Lerner (2004) argue that in reality many companies have been granted patents for trivial inventions or have exploited their intellectual property rights by threatening to sue the actual innovators.

Based on the above discussion, the standard knowledge production function can be extended to consider how finance (F_t) and patent laws (P_t) impact on knowledge production in the economy of India, and this yields:

$$g_A = \frac{\dot{A}_t}{A_t} = \lambda X_t^{\delta} A_t^{\phi-1} P_t^{\pi} F_t^{\theta}, \quad 0 < \delta \leq 1, \quad \phi < 1, \tag{3}$$

where P_t is measured by the extent of intellectual property rights protection and F_t is measured by financial liberalization or financial depth. The expected sign for π cannot be determined a priori as discussed above. θ is expected to carry a positive sign when F_t is measured by financial depth; but its sign is indeterminate when F_t is measured by financial liberalization. If both finance and intellectual property rights protection have no effect on ideas production (i.e. $\pi = \theta = 0$), the model reduces to the standard semi-endogenous growth model.

In steady state, theory predicts that the growth rate of A_t will be constant (see Ha and Howitt, 2007). Thus, this equation can be solved to see that A_t is proportional to X_t, F_t and P_t after taking logs, as follows:

$$\ln A_t = \beta_0 + \beta_1 \ln X_t + \beta_2 \ln P_t + \beta_3 \ln F_t + \varepsilon_t \tag{4}$$

where $\beta_0 = \ln \lambda /(1-\phi)$, $\beta_1 = \delta /(1-\phi)$, $\beta_2 = \pi /(1-\phi)$, $\beta_3 = \theta /(1-\phi)$ and ε_t is a stochastic error term. R&D input (X_t) will be measured by R&D personnel and R&D expenditure, patent protection will be measured by an index of intellectual property rights protection (P_t), and finance (F_t) will be measured by an index of financial liberalization or financial depth.[3] These are two different variables capturing different aspects of finance that could impact on innovations. While the above discussions suggest that financial deepening is likely to increase the provision of credit and hence facilitates ideas production, how financial liberalization affects innovation is unclear. Although the financial liberalization thesis of McKinnon (1973) and Shaw (1973) predicts a positive effect of financial liberalization on growth, alternative propositions of Mankiw (1986) and Stiglitz (1994) do not suggest positive growth effects following financial reforms. Furthermore, a growing empirical literature finds mixed results regarding the effect of financial liberalization on growth (see Eichengreen, 2002 for a recent survey). Therefore, β_1 is expected to carry a positive sign whereas the expected signs for β_2 and β_3 are ambiguous. The latter depends on how finance is measured. Eq. (4) will be tested using annual time series data for India over the period 1950-2006. Construction of variables and data sources will be discussed in the following section.

3. Data

3.1 Patent data

Inventive output can be measured by the number of patents filed by domestic residents, as suggested by Kortum (1993). The domestic stock of inventive output or knowledge (A_t) is constructed based on the number of patent applications filed at the Indian Patent Office by domestic residents.[4] Patent applications filed by Indian Residents at the U.S. Patent and Trademark Office are also considered in the robustness check section. Patent stock is computed using the perpetual inventory method with a depreciation rate of 10 percent. Data over the period 1919-2006 are used to get as precise a measure as possible of the knowledge stock in 1950. The initial knowledge stock is set equal to the number of patents in 1919 divided by the depreciation rate plus the average growth in patents over the period 1919-2006, which is the steady-state capital stock in the standard neoclassical growth models (see, e.g., Coe and Helpman, 1995). The patent data are obtained from the World Intellectual Property Organization (WIPO).

For the measurement of patent rights protection (P_t), we use the patent rights index compiled by Ginarte and Park (1997). The index covers five dimensions: (1) patentability of various

---

[3] For our purposes, financial deepening refers to the improvement in the extent and efficiency of a financial system where "extent" refers to the ease of access to financial services and "efficiency" refers to the effectiveness of the system in reducing information and transaction costs. Financial liberalization refers to the process of eliminating or significantly alleviating government-imposed financial system restrictions such as entry barriers, credit and interest controls, and capital flow restrictions (see Section 3.3 for more details).

[4] The four largest components of patent applications by domestic residents in India over the last decade are mechanical (22), chemical (21%), drug (17%) and electrical (14%) inventions.

kinds of inventions, (2) membership in international patent arrangements, (3) provisions for loss protection, (4) enforcement mechanisms, and (5) duration of the patent term. Each dimension is assigned a value ranging from zero to one. The unweighted sum of these five values provides an indication of the overall level of intellectual property rights protection, with higher values reflecting greater level of protection. The data are obtained from Park and Wagh (2002) and the updated patent rights index database of Ginarte and Park (1997) that provides data up to 2005. Missing years are interpolated and data before 1960 are assumed to be constant since there was no change in the patent laws of India during the period 1950-1960.

3.2 R&D measures

We use both R&D labor and real R&D expenditures as the proxies for R&D input (X_t). Missing data between years are linearly interpolated. The former refers to the number of scientists and technicians engaged in R&D activity, and the latter is deflated by an unweighted average of a wage index and the GDP deflator (see, e.g., Coe and Helpman, 1995). The R&D data are collected from various publications of “R&D Statistics” of the Department of Science and Technology and Planning Commission, Government of India. The Average daily wage index is obtained from various issues of the “Yearbook of Labor Statistics” published by the International Labor Office and the GDP deflator is compiled from various issues of "National Account Statistics" published by the Government of India.

3.3 Financial liberalization and financial depth

This study uses a broad-based financial liberalization index compiled by Abiad *et al.* (2008).[5] They consider seven policy dimensions as the inputs to construct the summary index: (1) credit controls and reserve requirements; (2) interest rate restraints; (3) entry barriers in the banking sector; (4) prudential regulations and supervision; (5) privatization in the financial sector; (6) restrictions on international capital flows; and (7) securities market policy. Along each dimension, a score of zero, one, two or three is assigned, indicating fully liberalized, partially liberalized, partially repressed, and fully repressed, respectively. The aggregation of these seven components is used to obtain an overall measure of financial liberalization. Following the same coding procedure, data before 1973 and after 2005 are extended using information obtained from the Annual Report and the Report on Currency and Finance of the Reserve Bank of India. Financial depth is measured using the ratio of private credit to GDP (see, e.g., Ang and McKibbin, 2007; Ang, 2008; Baltagi *et al.*, 2009).

[5] We are grateful to Abdul Abiad for providing the financial liberalization data.

[Figure 1 here]

Time series plots of the variables are presented in Figure 1. Except for the index of financial liberalization for which zeros are recorded for some years (when there is full financial repression or no financial liberalization), all variables are expressed in natural logarithms in the estimations. The accumulation of patents shows a steady increase during the first two decades. This process was accelerated following the economic reforms in the early 1990s. Both R&D personnel and real R&D expenditure exhibit a strong increasing trend over the last few decades. Evolution of the patent protection index matches closely with the policy changes in favor of a stronger framework, which mainly took place from the mid-1990s onwards. The composite financial liberalization index also coincides rather well with the actual policy changes that took place in India. The major reform occurred in 1991 when the central bank launched a series of liberalization programs, as reflected by an upward swing in the series since the early 1990s. Finally, unlike the radical changes that occurred in the policy environment of the financial system, the process of financial deepening appears to be much more steady and consistent.

4. Estimation Techniques

The dynamic adjustment of the ideas accumulation process can be characterized by the following conditional error-correction model (ECM), which can be used to test for the existence of a long-run relationship using the Autoregressive Distributed Lag (ARDL) bounds test developed by Pesaran *et al.* (2001):

$$\Delta \ln A_t = \alpha_0 + \beta_0 \ln A_{t-1} + \sum_{j=1}^{k} \beta_j \ln DET_{j,t-1} + \sum_{i=1}^{p} \gamma_{0i} \Delta \ln A_{t-i} + \sum_{i=0}^{p} \sum_{j=1}^{k} \gamma_{ji} \Delta \ln DET_{j,t-i} + \varepsilon_t \tag{5}$$

where A_t is patent stock, and DET_t is a vector of the determinants of innovative activity, which includes X_t, P_t and F_t. The above equation can be estimated by OLS since Pesaran and Shin (1998) have shown that the OLS estimators of the short-run parameters are consistent, and the ARDL based estimators of the long-run coefficients are super-consistent in small sample sizes. Hence, valid inferences on the long-run parameters can be made using standard normal asymptotic theory. The main advantage of this approach is that it can be applied to the model regardless of whether the underlying variables are $I(0)$ or $I(1)$.

Eq. (5) can be used to test for the existence of a long-run relationship using the ARDL bounds test developed by Pesaran *et al.* (2001). The test involves a simple F-test for the joint significance of coefficients on lagged levels terms of the conditional ECM

($H_0 : \beta_0 = \beta_1 = ... = \beta_k = 0$). The test for cointegration is provided by two asymptotic critical value bounds when the independent variables are either $I(0)$ or $I(1)$. The lower bound assumes all the independent variables are $I(0)$, and the upper bound assumes they are $I(1)$. If the test statistics exceed their respective upper critical values, the null is rejected and we can conclude that a long-run relationship exists. The long-run level relationship is then estimated using an ARDL model with (k+1) variables, where the orders of the model are chosen by searching across the $(p+1)^{k+1}$ ARDL models using the SBC criterion, as detailed in Pesaran and Shin (1998).

5. Empirical Results

5.1 The effects of finance and patent law on knowledge accumulation

Table 1 presents the results for the patent stock equation estimated using the ARDL procedure. The cointegration test results indicate that the null hypothesis of no level patent stock equation is rejected at the conventional levels of significance. This provides strong support in favor of the existence of a long-run relationship between knowledge accumulation and its determinants.[6] It is evident that the R&D variables enter the equation significantly at the one percent level with the expected sign. This finding is consistent with innovation-based endogenous growth models which predict that R&D plays an important role in bolstering innovative activity. Hence, more spending in R&D is likely to promote inventive activity that may in turn induce higher economic growth.

[Table 1 here]

With regard to intellectual property protection, our results suggest that increased patent protection appears to be beneficial for technological innovations. The patent law index enters all specifications significantly with a positive sign. In particular, a one percent increase in the index of intellectual property rights protection tends to increase knowledge accumulation by, on average, 0.56 percent when financial depth is used to proxy the availability of credit (Model A and Model C). The relationship appears to be one-to-one when the index of financial liberalization is considered (Model B and Model D). The results seem to suggest that stronger patent protection tends to boost the incentive to innovate, and thus stricter enforcement of intellectual property is an effective strategy to stimulate ideas accumulation in India. This result confirms the hypotheses of Gould and Gruben (1996), Maskus (2000) and O'Donoghue and Zweimüller (2005), which propose

[6] The integration properties of the variables are examined using the conventional Augmented Dickey-Fuller and Phillips-Perron tests, as well as the procedure of Lee and Strazicich (2003) that allows for the presence of structural breaks. In all cases, the variables are found to be either stationary, i.e. $I(0)$, or integrated at order one, i.e., $I(1)$, fulfilling the prerequisites for the use of the ARDL bounds test. The results are not reported but are available upon request.

that the rate of technical innovation increases with greater patent protection in the long run. Our results are broadly in line with the survey evidence of Levin *et al.* (1987) and the empirical findings of Kanwar and Evenson (2003) and Kanwar (2007).

Interestingly, while financial deepening is found to have a beneficial impact on knowledge accumulation, the direct effect of financial liberalization is found to be deleterious. The coefficients are strongly significant at the one percent level. The results are also found to be robust to the use of alternative financial depth indicators such as M2 over GDP and M3 over GDP. The use of three alternative coding procedures for the financial liberalization index as detailed in Ang (2009a) has also been considered. They give, by and large, very similar findings and therefore the results are not reported here to conserve space. The finding of a positive effect of financial deepening lends some support to the R&D-induced endogenous frameworks of de la Fuente and Marín (1996), Blackburn and Hung (1998), Aghion *et al.* (2005) and Aghion and Howitt (2009). The finding of a negative effect of financial liberalization is consistent with the financial repression thesis of Stiglitz (1994).

The results underscore the importance of deepening the financial system of India in order to stimulate productivity growth via the channel of facilitating innovative activity. Although financial repression may not be desirable, the evidence presented in this paper seems to provide some support to the argument that some form of financial restraint may help in boosting the availability of finance that facilitates innovation. However, as noted by Honohan and Stiglitz (2001), financial restraints are more likely to work well in environments with strong regulatory capacity. Although the legal system in India was originally based on the British model that emphasizes protection of property rights, India ended up with a much less effective institutional framework since the legal system was modified in a way that benefited the small number of Europeans who settled in and ran the economy (Mishkin 2006). This pinpoints the importance of strengthening the existing institutional framework in order to create a robust financial system that allows efficiency gains to be reaped, sustaining_economic growth in the long run. Unrestricted expansion in credit without adequate prudential regulation and supervision may induce instability in the financial system with potentially devastating effects.

5.2 Financial liberalization and knowledge accumulation: a further examination

The evidence presented in the previous section suggests that while financial deepening tends to stimulate knowledge accumulation, financial liberalization works in the opposite direction. The finding that financial liberalization tends to retard technological development is intriguing, and therefore a further analysis is warranted. Firstly, the results are obtained by entering these two finance variables separately in the regressions. Nevertheless, given that financial liberalization and financial deepening are two distinct aspects of finance emphasized in this paper, it would be interesting to see if the results remain robust to the inclusion of these two variables in the same specification. As is evident in columns (1a) and (1b) of Table 2, while the coefficients of financial liberalization are highly statistically significant and have the sign consistent with our previous findings, financial depth enters the equations significantly only in one of the two cases and the significance level of its coefficient is considerably weaker. These findings suggest that the effect of financial liberalization on knowledge accumulation is statistically stronger than that of financial depth.

[Table 2 here]

Next, we test whether there is a threshold effect in the relationship between financial liberalization and knowledge accumulation by including the squared term of financial liberalization in the specification. The results reported in columns (2a) and (2b) show that both the linear and non-linear terms of financial liberalization enter the equations significantly, providing evidence in favor of the presence of a threshold effect. The results further imply that financial liberalization will exert a beneficial impact only if the financial system is adequately liberalized. The turning point is found to be in the range of 6-6.5, a level that has been achieved since the mid-1990s. Thus, it appears that financial liberalization has negatively affected technological accumulation and innovations only in the early stages of development.

Moreover, we also examine how the effect of R&D activity on knowledge accumulation is shaped by financial reforms by including an interaction term between research activity and the financial liberalization index. The results in columns (3a) and (3b) suggest that the beneficial effect of R&D on knowledge stock can be enhanced through liberalization, although the direct effect of financial liberalization is negative.

Our estimates may be subject to endogeneity bias given that the measures of R&D may be affected by the strength of patent protection and the extent of credit constraint. We address this issue in the following ways. First, we consider a lagged measure of R&D activity since the decision to conduct research activity is unlikely to be driven by future finance and patent protection, which are often hard to predict. Second, we regress Eq. (4) using the vector error-correction model (VECM) so that all the underlying variables are treated as endogenous variables. The results reported in columns (4) and (5) show that our findings regarding how finance and patent laws affect patent accumulation remain largely unchanged.[7]

[7] We have attempted to regress R&D measures on finance and patent protection, following the approach of Kanwar and Evenson (2003) and Kanwar (2007). This, however, yields unsatisfactory regression results since the coefficients of both finance and patent protection turn out to be statistically insignificant.

6. Robustness

6.1 Alternative estimators

The sensitivity of the results in Table 1 based on the ARDL estimator is assessed using the following alternative single-equation estimators: 1) unrestricted error-correction model (UECM); 2) fully-modified OLS (FM-OLS); and 3) dynamic OLS (DOLS) procedures. The UECM estimator involves estimating the long-run parameters by incorporating adequate dynamics into the specification to avoid omitted lagged variable bias. In implementing this procedure, we follow Bewley (1979) by using the instrumental variable technique to correct the standard errors so that valid inferences can be drawn. Inder (1993) suggests that lagged level variables can be used as the instruments for the first-different current terms to correct for endogeneity bias. The FM-OLS procedure involves the use of the Wald tests where the resulting test statistics are "fully-modified" by semi-parametric corrections for serial correlation and for endogeneity. This "fully modified" procedure has been found to work well in finite samples, a feature which is particularly appealing given the small sample size used in the present study.

The key advantage of the DOLS procedure is that it allows for the presence of a mix of $I(0)$ and $I(1)$ variables in the cointegrated framework. The estimation involves regressing one of the $I(1)$ variables on the remaining $I(1)$ variables, the $I(0)$ variables, leads (p) and lags ($-p$) of the first difference of the $I(1)$ variables, and a constant. By doing so, it corrects for potential endogeneity problems and small sample bias, and provides estimates of the cointegrating vector which are asymptotically efficient.[8]

The results are reported in Table 3. Although the magnitude of the coefficients shows some variations, the qualitative aspects of the results are, by and large, consistent with those obtained using the ARDL estimator. The finding that R&D stimulates knowledge creation remains unchanged, regardless of whether it is measured by R&D labor or real R&D expenditure. In addition, we continue to find a positive and significant effect of patent protection. The finding that financial deepening facilitates inventive activity whereas financial liberalization does the opposite also remains unaltered. We therefore conclude that the results are insensitive to the choice of estimator.

[Table 3 here]

[8] All underlying variables are found to be either $I(0)$ or $I(1)$, and this allows legitimate use of the DOLS estimator. The unit root test results are not reported here to conserve space, but are available upon request.

6.2 Alternative patent measure

The analysis so far considers the accumulation of patent applications filed at the Indian Patent Office by domestic residents as the measure of knowledge stock. To provide a sensitivity check, we use the accumulation of patent applications filed by Indian residents at the U.S. Patent and Trademark Office as an alternative measure for knowledge stock in this section. The increase in the internationalization of R&D activity has rendered a significant number of the patents being filed in the U.S., although the research activity is conducted locally. However, although international patents are commonly used in the literature, they provide only an incomplete view of the aggregate inventive activities since most Indian firms do not systematically patent abroad. The average number of international patent applications filed over the last decade was less than one fifth of the domestic patent applications filed. International patents in this case mainly reflect the bilateral trade activities or technological collaborations between India and the U.S., given that most Indian firms applying for international patents are mainly U.S. companies with foreign subsidiaries in India. Since this research is mainly concerned with the effects of domestic finance and patent protection within India, the use of domestic patents is more appropriate. The estimates reported in Table 4 show that our core results remain largely unchanged by the consideration of this alternative measure, perhaps reflecting that the patents filed at the U.S. office are often duplicates of the domestic patents.

[Table 4 here]

6.3 Alternative estimation periods

Our results may be sensitive to the estimation period covered. To this end, we consider the following estimation periods: 1) 1960-2005; 2) 1970-2005; 3) 1980-2005; and 4) 1960-2000. The consideration of alternative estimation periods is important for two reasons. Firstly, the annual R&D data for the early years have been obtained by linear interpolation. Secondly, the patent law index shows a dramatic increase since the mid-1990s. The results reported in Table 5 show that the positive effects of R&D input and patent protection remains highly significant in all cases. Not surprisingly, the influence of patent law is found to be substantially smaller if the sample period is restricted to 1960-2000. The coefficients are found to be 0.417 and 0.247 in regressions (7) and (8), respectively, but remain highly significant. This robustness check suggests that our key findings regarding how knowledge accumulation is related to financial factors and patent protection are not significantly driven by the estimation period considered, although patent law has played a more important role in recent years.

[Table 5 here]

6.4 Control variables

To provide some further robustness checks for the results, we also control for transitional dynamics, macroeconomic instability, distance to the technology frontier, accumulated knowledge or patent stock generated by the rest of the world, and trade liberalization in the estimation. First, transitional dynamics are measured by the ratio of real investment to real GDP. The implications of transitional dynamics for growth have been highlighted in the models of Mulligan and Sala-i-Martin (1993), Peretto (1999) and Peretto and Smulders (2002). However, the empirical model in this paper is estimated under the assumption that India has been growing along its balanced growth path. To the extent that the economy of India may be out of its steady-state growth path, we cannot rule out the possibility that the estimates may have been affected by transitional dynamics.

Second, macroeconomic stability has often been argued to be an important factor for growth in the fast growing Asian economies (see, e.g.,; Fischer, 1996; Nelson and Pack, 1999). We use the standard deviation of the 12-month inflation rate as the measure of macroeconomic instability. The use of this measure is based on the assumption that periods of highly volatile exports, government revenues, public debts, financial and political instability tend to be associated with high inflation variability.

Third, Bernard and Jones (1996) argue that changes in innovative activity may also depend on technological catch-up. Countries which are relatively backward can grow faster by utilizing technologies developed in the leading country. To allow for this, we include a proxy for distance to the frontier, which is measured by the difference between total factor productivity (TFP) of the world technology leader (the U.S.) and TFP of India. TFP is recovered from Eq. (1) as $(Y_t / K_t^{\alpha} L_t^{1-\alpha})^{1/(1-\alpha)}$, where real output ($Y_t$) is measured by gross domestic product at constant prices, real capital stock (K_t) is the sum of non-residential buildings and structures (3% depreciation rate) and machinery and equipment (17% depreciation rate), L_t number of workers, and capital's share of income (π) is assumed to be 0.3.

Fourth, international knowledge may transmit across borders independently of the trade channel (see Bottazzi and Peri, 2007). In this case, the accumulation of patent stocks in the rest of the world may allow ideas to travel freely across borders. The world stock of knowledge available to India is simply the sum of all patent stocks across the world excluding India. Finally, trade liberalization is included in the equation because the literature often stresses outward orientation as an important factor behind the growth successes among the Asian growth miracles (see, e.g., Radelet *et al.*, 2001). It is proxied by the tariff rate (the ratio of import duties to total imports).

[Table 6 here]

These additional control variables are first entered separately and then jointly in equations (6) and (12), although the latter may give rise to some multicollinearity problems. Given that R&D labor and real R&D expenditure give similar results, we consider only the latter here since it is a more broad-based measure of R&D. The results reported in Table 6 indicate that the consideration of these additional conditioning variables does not alter our previous findings in any significant manner. Specifically, the investment ratio, which captures the effect of transitional dynamics, enters equations (1) and (7) positively and significantly. However, we do not find any statistically robust association between macroeconomic instability and the accumulation of ideas. The finding of a positive effect of the distance to the frontier in three out of four cases is consistent with the idea that countries which are relatively backward can grow faster by utilizing technologies developed in the leading country. Moreover, the finding of a positive effect of the world patent stock in most cases suggests that accumulated ideas from other countries could be used as the basis to generate further innovation in India. This finding is consistent with the "standing on shoulders" hypothesis of Jones (2002). Finally, openness to international trade tends to stimulate knowledge accumulation in India, and its effect is found to be statistically significant in all cases.

6. Conclusions

This paper has assessed the impact of finance and intellectual property protection on knowledge accumulation using annual time series data for India over the period 1950-2006. The study was motivated by the significant increase in the degree of financial liberalization observed across the developing world, and the lack of any previous attempts to jointly analyze the effect of finance and patent protection on knowledge in developing countries. The study contributes to the existing body of literature by investigating the unique experience of India, where its recent financial sector and patent system reforms provide an excellent case for further analysis. Amidst active debate on these reforms in India, the present study also provides timely information to guide policy formulation in developing countries.

Using the ARDL bounds cointegration techniques, the empirical evidence showed a significant long-run relationship between knowledge accumulation and its determinants. After documenting these basic cointegration results, we derived the long-run estimates using the ARDL estimator and several other estimators were also considered for robustness checks. The results suggest that while financial deepening facilitates the accumulation of ideas, financial liberalization appears to have a non-linear effect where knowledge accumulation first decreases with the degree of financial reforms, then stabilizes and eventually increases. The evidence presented in this paper also showed that stronger intellectual property protection has a beneficial effect on motivating innovation and technological deepening. Overall, the results are insensitive to the choice of estimation techniques, different measures of R&D input, alternative estimation period, different patent measure, and the inclusion of other relevant macroeconomic variables.

The findings of this paper have important policy implications for developing countries. To the extent that financial deepening has a positive effect in generating innovations while financial sector reforms may act in the opposite direction in the early stages of development, it is critical to develop a robust financial system with adequate provision of both credit and prudential regulations in order to motivate inventive activity. Moreover, given that more stringent patent policies are likely to have a positive impact on technological deepening, although it is a costly exercise, conforming to international requirements towards enforcing more stringent intellectual property rights may provide greater incentives for innovation in developing countries. Moreover, the results also show that R&D is an important determinant for innovation-based growth, providing some support to the notion that R&D-based endogenous growth models are useful in explaining the growth phenomenon in the context of a developing economy.

Our study should be seen in the context of a burgeoning theoretical and empirical literature on R&D-induced endogenous growth models. While the empirical results presented in this study are intriguing, more analysis is warranted. We hesitate to generalize the findings of this study to other developing countries since the results may be unique to the experience of India due to its own institutional and historical settings. Further case studies are desirable to gain more insight into the effect of finance and patent protection on ideas production, particularly with the developing countries' experience, using the framework established in this paper. To what extent the findings in this paper are specific to the experience of India or can be applied to other developing countries is left for future research when R&D data for other developing countries become more widely available.

References

Abiad, A., E. Detragiache & T. Tressel (2008) 'A New Database of Financial Reforms', *IMF Working Paper No. 266,*

Aghion, P. & P. Howitt (1992) 'A Model of Growth through Creative Destruction', *Econometrica,* 60, 323-51

Aghion, P. & P. Howitt (1998) *Endogenous growth theory,* (Cambridge, MA: MIT Press)

Aghion, P. & P. Howitt (2009) *The Economic of Growth,* (Cambridge, Massachusetts: The MIT Press)

Aghion, P., P. Howitt & D. Mayer-Foulkes (2005) 'The Effect of Financial Development on Convergence: Theory and Evidence', *Quarterly Journal of Economics,* 120, 173-222

Ang, J. B. (2008) 'What Are the Mechanisms Linking Financial Development and Economic Growth in Malaysia?', *Economic Modelling,* 38, 38-53

Ang, J. B. (2009a) 'Finance and Inequality: The Case of India', *Southern Economic Journal, forthcoming,*

Ang, J. B. (2009b) 'Private Investment and Financial Sector Policies in India and Malaysia', *World Development,* 37, 1261-73

Ang, J. B. (2009c) 'Research, Technological Change and Financial Liberalization in South Korea', *Journal of Macroeconomics, forthcoming,* (doi:10.1016/j.jmacro.2009.06.002)

Ang, J. B. & J. B. Madsen (2008) 'Knowledge Production, Financial Liberalization and Growth', *Paper presented at the Financial Development and Economic Growth conference, Monash University, April 2008*

Ang, J. B. & W. J. McKibbin (2007) 'Financial Liberalization, Financial Sector Development and Growth: Evidence from Malaysia', *Journal of Development Economics,* 84, 215-33

Arestis, P. & P. O. Demetriades (1997) 'Financial Development and Economic Growth: Assessing the Evidence', *Economic Journal,* 107, 783-99

Baltagi, B. H., P. Demetriades & S. H. Law (2009) 'Financial Development and Openness: Evidence from Panel Data', *Journal of Development Economics, forthcoming,*

Beck, T. & R. Levine (2004) 'Stock Markets, Banks, and Growth: Panel Evidence', *Journal of Banking and Finance,* 28, 423-42

Bekaert, G., C. R. Harvey & C. Lundblad (2005) 'Does Financial Liberalization Spur Growth?', *Journal of Financial Economics,* 77, 3-55

Bernard, A. B. & C. I. Jones (1996) 'Comparing Apples to Oranges: Productivity Convergence and Measurement Across Industries and Countries', *American Economic Review,* 86, 1216-38

Bewley, R. (1979) 'The Direct Estimation of the Equilibrium Response in a Linear Dynamic Model.', *Economics Letters,* 3, 357-61

Blackburn, K. & V. T. Y. Hung (1998) 'A Theory of Growth, Financial Development and Trade', *Economica,* 65, 107-24

Boldrin, M. & D. K. Levine (2008) *Against Intellectual Monopoly,* (Cambridge: Cambridge University Press)

Bottazzi, L. & G. Peri (2007) 'The International Dynamics of R&D and Innovation in the Long Run and in The Short Run', *Economic Journal,* 117, 486-511

Coe, D. T. & E. Helpman (1995) 'International R&D spillovers', *European Economic Review,* 39, 859-97

de la Fuente, A. & J. M. Marín (1996) 'Innovation, Bank Monitoring, and Endogenous Financial Development', *Journal of Monetary Economics,* 38, 269-301

Demetriades, P. O. & K. A. Hussein (1996) 'Does Financial Development Cause Economic Growth? Time-Series Evidence from Sixteen Countries', *Journal of Development Economics,* 51, 387-411

Edison, H., R. Levine, L. Ricci & T. Sløk (2002) 'International Financial Integration and Economic Growth', *Journal of International Money and Finance,* 21, 749-76

Eichengreen, B. (2002) 'Capital Account Liberalization: What Do the Cross-Country Studies Tell Us?', *World Bank Economic Review,* 15, 341-66

Falvey, R., N. Foster & D. Greenaway (2006) 'Intellectual Property Rights and Economic Growth', *Review of Development Economics,* 10, 700-19
Fischer, S. (1996) 'Lessons from East Asia and the Pacific Rim', *Brookings Papers on Economic Activity,* 2, 345-50
Gilbert, R. & D. Newbery (1982) 'Preemptive Patenting and the Persistent of Monopoly', *American Economic Review,* 72, 514-26
Ginarte, J. & W. Park (1997) 'Determinants of Patent Rights: A Cross-National Study', *Research Policy,* 26, 283-301
Gould, D. & W. Gruben (1996) 'The Role of Intellectual Property Rights in Economic Growth', *Journal of Development Economics,* 48, 323-50
Grossman, G. M. & E. Helpman (1991) 'Quality Ladders in the Theory of Growth', *Review of Economic Studies,* 58, 43-61
Ha, J. & P. Howitt (2007) 'Accounting for Trends in Productivity and R&D: A Schumpeterian Critique of Semi-Endogenous Growth Theory', *Journal of Money, Credit and Banking,* 39, 733-74
Hall, B. H. (1992) 'Investment and Research and Development at the Firm Level: Does the Source of Financing Matter?', *NBER Working Papers 4096,*
Helpman, E. (1993) 'Innovation, Imitation, and Intellectual Property Rights', *Econometrica,* 61, 1247-80
Himmelberg, C. P. & B. C. Petersen (1994) 'R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries', *Review of Economics and Statistics,* 76, 38-51
Honohan, P. & J. E. Stiglitz (2001) 'Robust Financial Restraint', in *Financial Liberalization: How Far, How Fast?,* eds. G. Caprio, P. Honohan and J. E. Stiglitz (Cambridge: Cambridge University Press)
Howitt, P. (1999) 'Steady Endogenous Growth with Population and R&D Inputs Growing', *Journal of Political Economy,* 107, 715-30
Inder, B. (1993) 'Estimating Long-Run Relationships in Economics: A Comparison of Different Approaches', *Journal of Econometrics,* 57, 53-68
Jaffe, A. B. & J. Lerner (2004) *Innovation and Its Discotents,* (Princeton: Princeton Universsity Press)
Jones, C. (1995a) 'R&D Based Models of Economic Growth', *Journal of Political Economy,* 103, 759-84
Jones, C. (1995b) 'Time Series Tests of Endogenous Growth Models', *Quarterly Journal of Economics,* 110, 495-525
Jones, C. (2002) *Introduction to Economic Growth,* (New York and London: W. W. Norton & Company)
Kanwar, S. (2007) 'Business Enterprise R&D, Technological Change, and Intellectual Property Protection', *Economics Letters,* 96, 120-26
Kanwar, S. & R. Evenson (2003) 'Does Intellectual Property Protection Spur Technological Change?', *Oxford Economic Papers,* 55, 235-64
Kanwar, S. & R. Evenson (2009) 'On the Strength of Intellectual Property Protection that Nations Provide', *Journal of Development Economics,* 90, 50-56
Kortum, S. (1993) 'Equilibrium R&D and the Patent-R&D Ratio: U.S. Evidence', *American Economic Review.,* 83, 450-57
Kortum, S. (1997) 'Research, Patenting, and Technological Change', *Econometrica,* 65, 1389-419
Lai, E. (1998) 'International Intellectual Property Rights Protection and the Rate of Product Innovation', *Journal of Development Economics*, 55, 133-53
Laincz, C. & P. Peretto (2006) 'Scale Effects in Endogenous Growth Theory: An Error of Aggregation, Not Specification', *Journal of Economic Growth,* 11, 263-88
Lee, J. & M. C. Strazicich (2003) 'Minimum Lagrange Multiplier Unit Root Test with Two Structural Breaks', *Review of Economics and Statistics,* 85, 1082-89

Lerner, J. (2009) 'The Empirical Impact of Intellectual Property Rights on Innovation: Puzzles and Clues', *American Economic Review,* 99, 343-48

Levin, R. C., A. K. Klevorick, R. R. Nelson & S. G. Winter (1987) 'Appropriating the Returns from Industrial Research and Development', *Brookings Papers on Economic Activity,* 18, 783-832

Liodakis, G. (2008) 'Finance and Intellectual Property rights as the Two Pillars of Capitalism Changes', in *Powerful Finance and Innovation Trends in A High-risk Economy,* eds. B. Laperche and D. Uzunidis (Hampshire: Palgrave Macmillan)

Mankiw, N. G. (1986) 'The Allocation of Credit and Financial Collapse', *Quarterly Journal of Economics,* 101, 455-70

Maskus, K. (2000) 'Intellectual Property Rights and Economic Development', *Case Western Journal of International Law,* 32, 471-506

Mavrotas, G. & S.-I. Son (2006) 'Financial Sector Development and Growth: Re-examining the Nexus', in *Transparency, Governance and Markets,* eds. M. Bagella, L. Becchetti and I. Hasan (Amsterdam: Elsevier Science)

McKinnon, R. I. (1973) *Money and Capital in Economic Development,* (Washington, D.C.: Brookings Institution)

Mishkin, F. S. (2006) *The Next Great Globalization: How Disadvantaged Nations Can Harness Their Financial Systems to Get Rich,* (Princeton and Oxford: Princeton University Press)

Mulligan, C. & X. Sala-i-Martin (1993) 'Transitional Dynamics in Two-Sector Models of Endogenous Growth', *Quarterly Journal of Economics,* 108, 739-73

Nelson, R. R. & H. Pack (1999) 'The Asian Growth Miracle and Modern Growth Theory', *Economic Journal,* 109, 416

O'Donoghue, T. & J. Zweimüller (2005) 'Patents in A Model of Endogenous Growth', *Journal of Economic Growth,* 9, 81-123

Park, W. & J. Ginarte (1997) 'Intellectual Property Rights and Economic Growth', *Contemporary Economic Policy,* 15, 51-61

Park, W. G. & S. Wagh (2002) 'Index of Patent Rights', in *Economic Freedom of the World: 2002 Annual Report,* eds. J. Gwartney and R. Lawson (Washington, D.C.: The Cato Institute)

Peretto, P. (1998) 'Technological Change and Population Growth', *Journal of Economic Growth,* 3, 283-311

Peretto, P. & S. Smulders (2002) 'Technological Distance, Growth and Scale Effects', *Economic Journal,* 112, 603-24

Peretto, P. F. (1999) 'Industrial Development, Technological Change, and Long-run Growth', *Journal of Development Economics,* 59, 389-417

Pesaran, M. H. & Y. Shin (1998) 'An Autoregressive Distributed-Lag Modelling Approach to Cointegration Analysis', in *Econometrics and Economic Theory in the Twentieth Century: The Ragnar Frisch Centennial Symposium,* ed. S. Strom (Cambridge: Cambridge University Press)

Pesaran, M. H., Y. Shin & R. J. Smith (2001) 'Bounds Testing Approaches to the Analysis of Level Relationships', *Journal of Applied Econometrics,* 16, 289-326

Radelet, S., J. Sachs & J.-W. Lee (2001) 'The Determinants and Prospects of Economic Growth in Asia', *International Economic Journal,* 15, 1-29

Rioja, F. & N. Valev (2004) 'Finance and the Sources of Growth at Various Stages of Economic Development', *Economic Inquiry,* 42, 127-40

Romer, P. M. (1990) 'Endogenous Technological Change', *Journal of Political Economy,* 98, S71-102

Rousseau, P. L. & D. Vuthipadadorn (2005) 'Finance, Investment, and Growth: Time Series Evidence from 10 Asian Economies', *Journal of Macroeconomics,* 27, 87-106

Segerstrom, P. S. (1998) 'Endogenous Growth without Scale Effects', *American Economic Review,* 88, 1290-310

Segerstrom, P. S., T. C. A. Anant & E. Dinopoulos (1990) 'A Schumpeterian Model of the Product Life Cycle', *American Economic Review,* 80, 1077-91

Shaw, E. S. (1973) *Financial Deepening in Economic Development,* (New York: Oxford University Press)

Solow, R. M. (2001) 'Applying Growth Theory across Countries', *World Bank Economic Review,* 15, 283-88

Stiglitz, J. E. (1994) 'The Role of the State in Financial Markets', in *Proceedings of the World Bank Annual Conference on Development Economics, 1993: Supplement to The World Bank Economic Review and The World Bank Research Observer,* eds. M. Bruno and B. Pleskovic (Washington, D.C.: World Bank)

Table 1: ARDL estimates and bounds tests (1950-2006)

Dep. = patent stock (A_t)	Model A	Model B	Model C	Model D
Intercept	1.321*** (0.000)	6.003*** (0.000)	7.695*** (0.000)	8.912*** (0.000)
R&D labor	0.512*** (0.000)	0.241*** (0.000)		
Real R&D expenditure			0.368*** (0.000)	0.186*** (0.000)
Patent law	1.093*** (0.000)	0.556*** (0.000)	0.953*** (0.000)	0.563*** (0.000)
Financial liberalization	-0.052*** (0.000)		-0.037*** (0.000)	
Financial depth		0.361*** (0.000)		0.346*** (0.002)
ARDL Bounds test statistic	4.49**	5.18**	4.09*	6.28***

Notes: The test statistics of the bounds tests are compared against the critical values reported in Pesaran *et al.* (2001). The estimation allows for an unrestricted intercept and no trend. The 10%, 5% and 1% critical value bounds for the *F*-test are (2.72, 3.77), (3.23, 4.35) and (4.29, 5.61), respectively. *, ** and *** indicate 10%, 5% and 1% levels of significance, respectively.

Table 2: A further examination on the effect of financial liberalization on knowledge accumulation (1950-2006)

Dep. = patent stock (A_t)	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)	(5a)	(5b)
	Joint effects		Non-linearity		Fin. Lib. x R&D		Lagged R&D		VECM estimate	
Intercept	1.16	8.92$^{\#}$	2.56$^{\#}$	8.22$^{\#}$	2.58$^{\#}$	8.51$^{\#}$	1.52$^{\#}$	7.84$^{\#}$	1.58	8.01
R&D labor	0.53$^{\#}$		0.45$^{\#}$		0.44$^{\#}$		0.51$^{\#}$		0.50$^{\#}$	
Real R&D expenditure		0.21^{+}		0.31$^{\#}$		0.18$^{\#}$		0.36$^{\#}$		0.32$^{\#}$
Patent law	0.96$^{\#}$	0.51^{+}	0.62$^{\#}$	0.29*	0.81$^{\#}$	0.39^{+}	0.96$^{\#}$	0.76$^{\#}$	1.26$^{\#}$	1.63$^{\#}$
Financial liberalization	-0.08$^{\#}$	-0.07$^{\#}$	-0.12$^{\#}$	-0.13$^{\#}$	-0.36^{+}	-0.25$^{\#}$	-0.09$^{\#}$	-0.09$^{\#}$	-0.13$^{\#}$	-0.23$^{\#}$
Financial depth	-0.03	0.39*								
(Financial liberalization)^2			0.01$^{\#}$	0.01$^{\#}$						
Financial liberalization x R&D					0.02*	0.05$^{\#}$				

Notes: *, + and # indicate 10%, 5% and 1% levels of significance, respectively.

Table 3: Alternative estimates for the knowledge accumulation function (1950-2006)

Dep. = patent stock (A_t)	Model A R_t = R&D labor F_t = financial liberalization	Model B R_t = R&D labor F_t = financial depth	Model C R_t = real R&D expenditure F_t = financial liberalization	Model D R_t = real R&D expenditure F_t = financial depth
<u>I. UECM</u>				
Intercept	1.486***	7.843***	7.709***	8.951***
R&D (R_t)	0.515***	0.149**	0.377***	0.180**
Patent law (P_t)	0.974***	0.394***	0.803***	0.518***
Finance (F_t)	-0.085***	0.546**	-0.092***	0.317**
<u>II. FMOLS</u>				
Intercept	1.295***	5.956***	7.699***	8.945***
R&D (R_t)	0.514***	0.245***	0.369***	0.184**
Patent law (P_t)	1.093***	0.547***	0.948***	0.561***
Finance (F_t)	-0.053***	0.374***	-0.037***	0.361**
<u>III. DOLS</u>				
Intercept	1.742***	4.965***	7.972***	9.368***
R&D (R_t)	0.501***	0.309***	0.325***	0.131*
Patent law (P_t)	1.091***	0.784***	0.909***	0.291*
Finance (F_t)	-0.049***	0.259**	-0.062***	0.387***

Notes: *, ** and *** indicate 10%, 5% and 1% levels of significance, respectively.

Table 4: Estimates based on alternative patent measure (1950-2006)

Dep. = patent stock (A_t)	Model A	Model B	Model C	Model D
Intercept	-17.916***	-10.913***	1.152***	2.446***
R&D labor	1.528***	1.121***		
Real R&D expenditure			1.101***	0.899***
Patent law	2.279***	1.277***	1.809***	1.290***
Financial liberalization	-0.095***		-0.054***	
Financial depth		0.489***		0.343**

Notes: ** and *** indicate 5% and 1% levels of significance, respectively.

Table 5: Estimates of alternative estimation periods (1950-2006)

Dep. = patent stock (A_t)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	1960-2005		1970-2005		1980-2005		1960-2000	
Intercept	7.879***	8.938***	8.203***	8.663***	7.893***	8.621***	8.187***	9.132***
Real R&D expenditure	0.306***	0.168***	0.194***	0.158***	0.279***	0.168***	0.278***	0.153***
Patent law	0.916***	0.603***	0.964***	0.779***	0.988***	0.773***	0.417**	0.247**
Financial liberalization	-0.023***		-0.007		-0.017**		-0.019***	
Financial depth		0.336***		0.179*		0.175		0.327***

Notes: *, ** and *** indicate 10%, 5% and 1% levels of significance, respectively.

Table 6: Controlling for the effects of other macroeconomic variables (1950-2006)

Dep. = patent stock (A_t)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Intercept	8.68$^{\#}$	7.57$^{\#}$	6.94$^{\#}$	-12.29^{+}	7.53$^{\#}$	1.29	9.82$^{\#}$	8.63$^{\#}$	7.72$^{\#}$	0.71	9.23$^{\#}$	-0.84
Real R&D expenditure	0.30$^{\#}$	0.41$^{\#}$	0.34$^{\#}$	0.01	0.35$^{\#}$	0.18*	0.15$^{\#}$	0.24$^{\#}$	0.17$^{\#}$	-0.09	0.12*	0.22
Patent law	0.83$^{\#}$	0.92$^{\#}$	1.03$^{\#}$	0.91$^{\#}$	1.04$^{\#}$	0.66^{+}	0.57$^{\#}$	0.55$^{\#}$	0.96$^{\#}$	0.39$^{\#}$	0.62$^{\#}$	0.65^{+}
Financial liberalization	-0.03$^{\#}$	-0.04$^{\#}$	-0.19^{+}	-0.07$^{\#}$	-0.04$^{\#}$	-0.05^{+}						
Financial depth							0.25$^{\#}$	0.28^{+}	0.37$^{\#}$	0.58$^{\#}$	0.56$^{\#}$	0.75$^{\#}$
Transitional dynamics	0.53$^{\#}$					0.28	0.69$^{\#}$					-0.02
Macroeconomic instability		-0.05				0.02		-0.03				0.07
Distance to the frontier			0.79$^{\#}$			-0.31			1.12$^{\#}$			0.47$^{\#}$
Rest of world patent stock				1.41$^{\#}$		0.53				0.63*		0.71$^{\#}$
Trade liberalization					0.22*	0.16^{+}					0.24$^{\#}$	0.21*

Notes: *, + and # indicate 10%, 5% and 1% levels of significance, respectively.

Figure 1*:* Time series plots of variables (1950-2006)